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Diapycnal oxygen supply to the tropical North Atlantic oxygen minimum zone (OMZ)

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Diapycnal diffusivity

Diapycnal diffusivity K describes diffusive transport across surfaces of constant density. Basically K is specific for the transported quantity and is determined by three contributing processes:

$$K = K_{molecular} + K_{turbulent} + K_{salt\text{-}finger\text{-}enhancement}$$

[St. Laurent and Schmitt 1999]

In the region of the tropical North Atlantic OMZ in the depth range 150m to 500m, turbulence is the dominant mixing process, molecular and double diffusive components are negligible. Thus K can be determined by methods that measure turbulent diapycnal mixing, e.g. microstructure shear probes.

Diapycnal flux

Diapycnal flux is then defined as the flux across isopycnals that is driven by K acting on a gradient:

$$\Phi = -K \cdot \frac{\partial}{\partial z} c$$

[Gregg 1987]

with K diapycnal diffusivity, c concentration of the quantity in focus, and Φ resulting diapycnal flux. The diapycnal gradient can be approximated by the vertical gradient.

Diapycnal supply

Diapycnal supply of a quantity is the difference between flux into a volume and flux out of that volume. Diapycnal supply can be expressed as negative vertical divergence of diapycnal flux:

$$-\frac{\partial}{\partial z}\Phi = K \cdot \frac{\partial^2}{\partial z^2} c$$

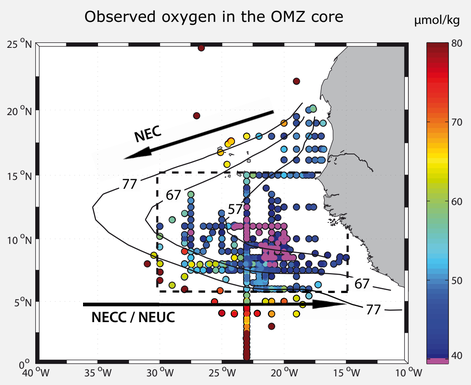
with K diapycnal diffusivity, c concentration of the quantity in focus, and Φ diapycnal flux. Diapycnal supply is the quantity to study when quantifying the terms of an oxygen budget:

Consumption rate + diapycnal supply + isopycnal supply = 0 (in steady state).

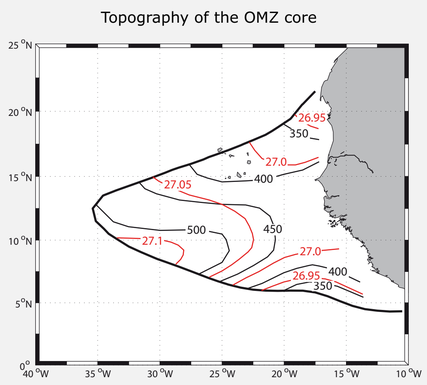
The oxygen minimum zone of the tropical North Atlantic

Horizontal structure of the OMZ

Data was acquired during 6 cruises in 2008 to 2010

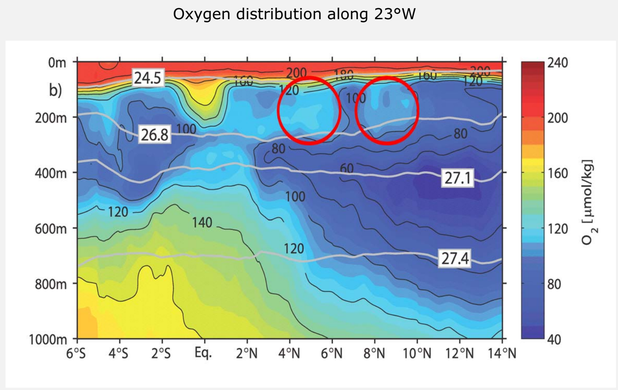


Oxygen isolines are from World Ocean Atlas 2009 [Garcia et al. 2010]. The 77 µmol/kg isoline describes well the 60 µmol/kg observations. Observed absolute minimum was about 40µmol/kg. NEC: North Equatorial Current, NECC: North Equatorial Countercurrent, NEUC: North Equatorial Undercurrent.

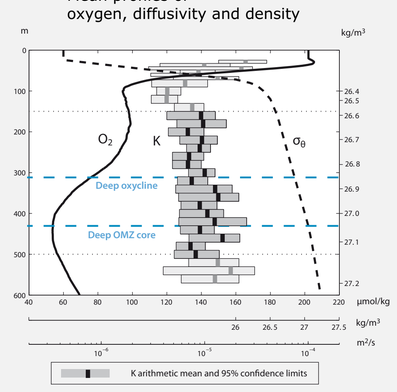


The vertical position of the OMZ core varies within the OMZ as limited by the 60 µmol/kg observations. Depth isolines (black) and density isolines (red) are shown.

Vertical structure of the OMZ



Isolines of oxygen concentration (black) and lines of constant density (white). Eastward current bands coincide with higher oxygen concentrations in the upper 250m. From [Brandt et al. 2010].

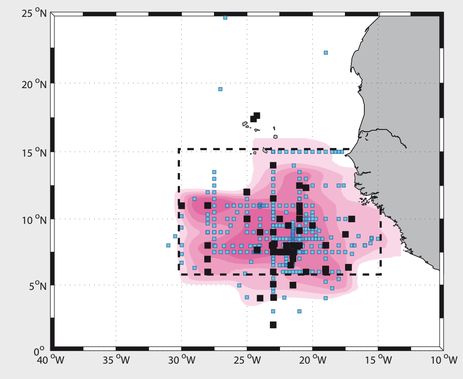


In the depth range 150m to 500m (dashed black lines) we have complete datasets comprising diapycnal diffusivity K and vertical oxygen gradients. K and stratification are about constant in 150m to 500m.

Vertical structure of the diapycnal oxygen supply and the oxygen budget

Dataset of diapycnal diffusivities

from cruises in 2008 to 2010



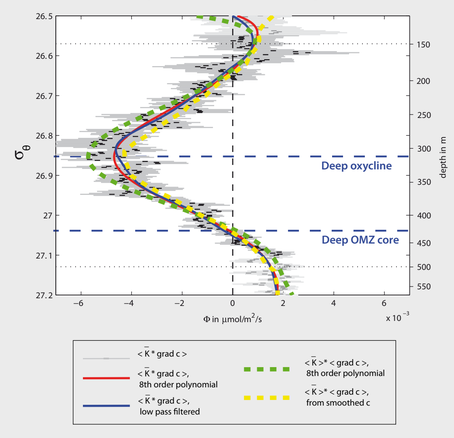
from a Tracer Release Experiment [Banyte et al. 2012] K = (1.2 ± 0.2) x 10^{-5} m^2/s

from microstructure profiles

from velocity profiles by vessel mounted ADCP } K = (0.95 ± 0.15) x 10^{-5} m^2/s

Diapycnal oxygen flux profile

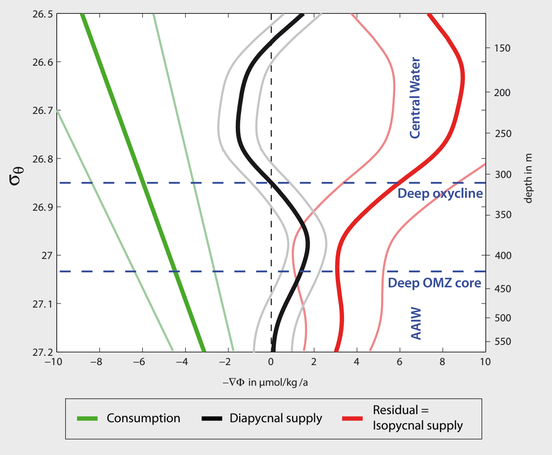
estimated from different methods from diapycnal K and O_2 gradient



Maximum downward diapycnal flux happens in the maximum oxygen gradient. There is no direct diapycnal oxygen flux from the ocean surface or from below the OMZ core.

Vertical structure of the oxygen budget

Consumption rate = diapycnal supply + isopycnal supply



An estimated profile of consumption rate specific for the tropical North Atlantic OMZ [Karstensen et al. 2008] allows to infer the profile of isopycnal oxygen supply from the budget equation.

Main results:

30 % of supply of the OMZ core is diapycnal.

Oxygen is brought laterally by zonal flow, then redistributed diapycnally in the OMZ.

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